Single shot partial dual echo (SPADE) EPI - An efficient acquisition scheme for whole brain fMRI

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Background: Most fMRI studies are based on gradient echo EPI (GE-EPI). In general, GE-EPI is more sensitive to changes in the blood oxygenation level dependent (BOLD) contrast than spin echo EPI (SE-EPI). On the other hand, SE-EPI is considerably more robust against signal losses caused by magnetic field inhomogeneities, which typically occur in brain regions near air-tissue interfaces, such as the inferior frontal, the medial temporal and the inferior temporal lobes (1,2). Using the SE signal in critical regions (i.e. regions affected by field inhomogenieties) and the GE signal for normal regions therefore seems an attractive option. An efficient method for interleaving the acquisition of GE and SE images is the single shot dual echo EPI sequence (1). Following the acquisition of a GE EPI image, a slice-selective 180 degree refocusing pulse is applied and a second (SE-EPI) image is acquired such that the spin echo occurs in the centre of k-space of that image.

The problem: For most fMRI applications, the dual echo acquisition scheme is suboptimal for a number of reasons: (i) more than a 100% increase in the minimum repetition time (TR), because two images are acquired per slice; (ii) the resulting temporal resolution is often insufficient for event-related fMRI designs; (iii) the resulting time normalised SNR is suboptimal; (iv) the 180 degree refocusing pulses lead to a substantial increase in the SAR (specific absorption rate) which may be particularly problematic at high and ultrahigh field strength.

Our solution: We propose to acquire additional SE images only where necessary, which means for those slices that are actually affected by signal losses or voids in the GE-EPI images (cf. Figure 1). We refer to this acquisition scheme as SPADE (Single shot Partial Dual Echo) imaging. Typically, magnetic field inhomogeneities only affect the lower third of the brain. By restricting the acquisition of additional SE images to this region, SPADE provides a much more efficient acquisition scheme than the conventional single shot dual echo approach. This not only considerably reduces the minimum TR, but also enables whole brain coverage in less than 2.9 s (32 slices, slice thickness: 3 mm, matrix size: 64 x 64), providing a temporal resolution sufficient for most event-related fMRI designs. The time normalised SNR can be considered optimal, as no time is wasted with acquiring SE-images that aren't actually needed. The reduced number of spin echoes also results is a significantly lower SAR, which makes SPADE particularly attractive for high and ultrahigh field applications.

Methods and preliminary results: The SPADE sequence was implemented on a 3 Tesla whole body scanner (Siemens Magnetom Tim Trio, Siemens Medical Solutions, Erlangen, Germany). Figure 2 shows the results obtained in a healthy volunteer. 32 transversal-oblique slices were acquired to cover the whole brain (slice thickness: 3 mm, slice gap: 0.75 mm, matrix size: 64 x 64, field of view: 192 x 192 mm, in-plane resolution: 3 x 3 mm). Additional spin echo images were acquired only for the lower 12 slices. The resulting minimum repetition time was TR = 2.9 s. The corresponding echo times were 30 and 102 ms. A comparison of the two enlarged images clearly shows that the typical signal voids visible in the gradient echo image are absent in the spin echo image.

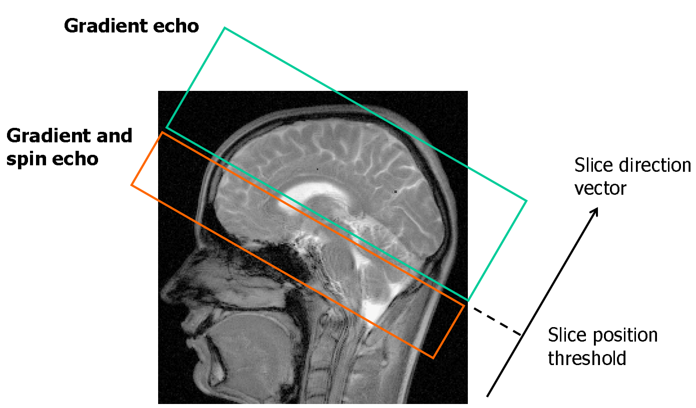

Fig. 1. The SPADE acquisition scheme. Additional spin echo images are only acquired for the lower part of the brain where signal losses due to magnetic field inhomogeneity typically occur. The corresponding slice position threshold can be specified by the user.

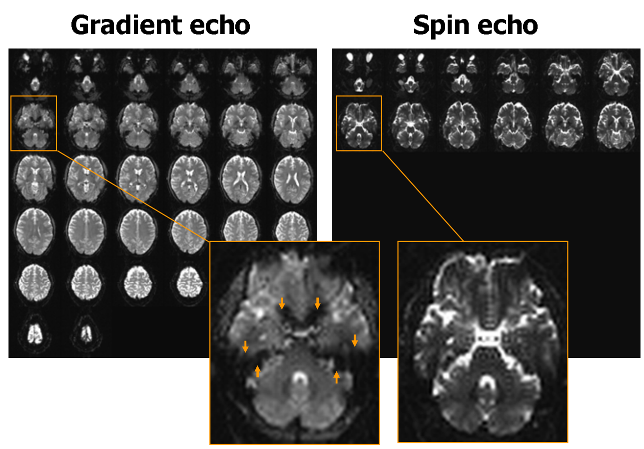

Fig. 2. Preliminary results obtained in a healthy volunteer using the SPADE sequence. The orange arrows indicate areas of signal voids in the enlarged gradient echo image, which are not present in the corresponding spin echo image.

Conclusion: SPADE imaging provides an efficient solution for whole brain fMRI applications. Signal loss in brain areas affected by magnetic field inhomogeneity can be significantly reduced at the expense of a comparatively small increase in the TR and SAR. This makes SPADE an attractive option for fMRI applications where whole brain coverage (and sensitivity) is required.

References:

1. Bandettini PA et al., NMR in Biomedicine 1994; 7(1-2):12-20.
2. Norris DG, Journal of Magnetic Resonance Imaging 2006; 23(6):794-807.